Long-term Trichloroethylene Detoxification in Low-Permeability Soil via Electrokinetic-Enhanced Bioremediation: Feasibility and Spatial-Temporal Patterns

Si-Ying YANG[1], Li-Dan ZHANG[1], He-Ping ZHAO[1]*

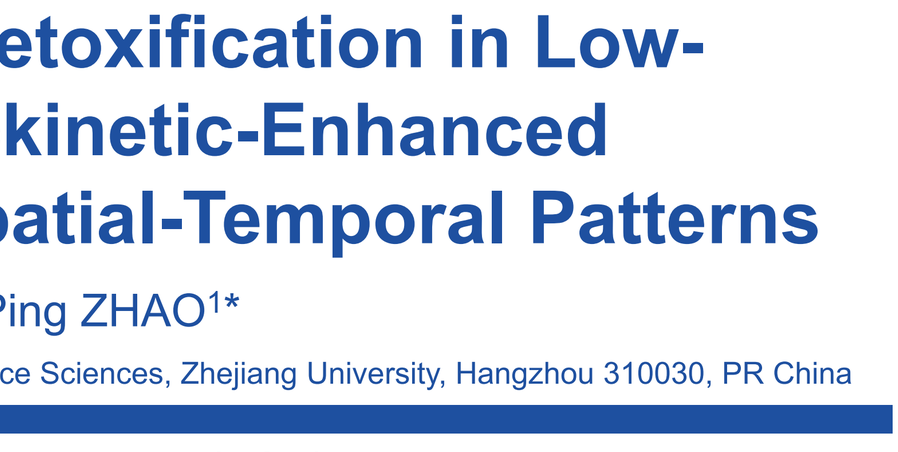
1. MOE Key Lab of Environmental Remediation and Ecosystem Health, College of Environmental and Resource Sciences, Zhejiang University, Hangzhou 310030, PR China

Motivation To remediate low-permeability soil contaminated with trichloroethylene (TCE), combining bioremediation with the electrokinetic technique offers an innovative technology for *in-situ* treatment. In recent years, although the electrokinetic-enhanced bioremediation system (EK-BIO) has been demonstrated as a novel environmentally friendly technology with the potential to degrade several chlorinated hydrocarbons, the influencing mechanisms of electrode reactions in the EK-BIO system on long-term dechlorination are still poorly understood. Therefore, in this study, we aimed to assess the feasibility of the long-term operation of the EK-BIO system and to examine the spatial and temporal patterns of TCE detoxification in contaminated low-permeability soil.

Experiment Setup

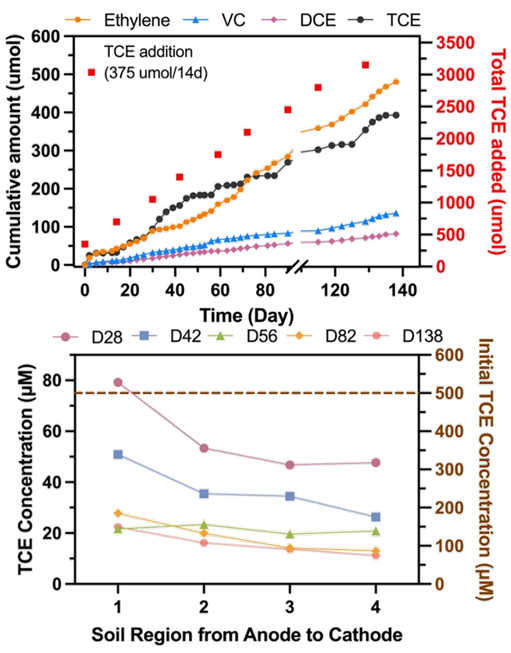
To investigate the spatial-temporal variations within the EK-BIO system, five 1-dimensional acrylic columns were set up in parallel only changing their operation period (28, 42, 56, 70 and 84 days). After a certain operation time, the soil in different regions was inoculated into anaerobic culture to evaluate the TCE degradation activity after EK enhancement.

Figure 1



Results and Discussion

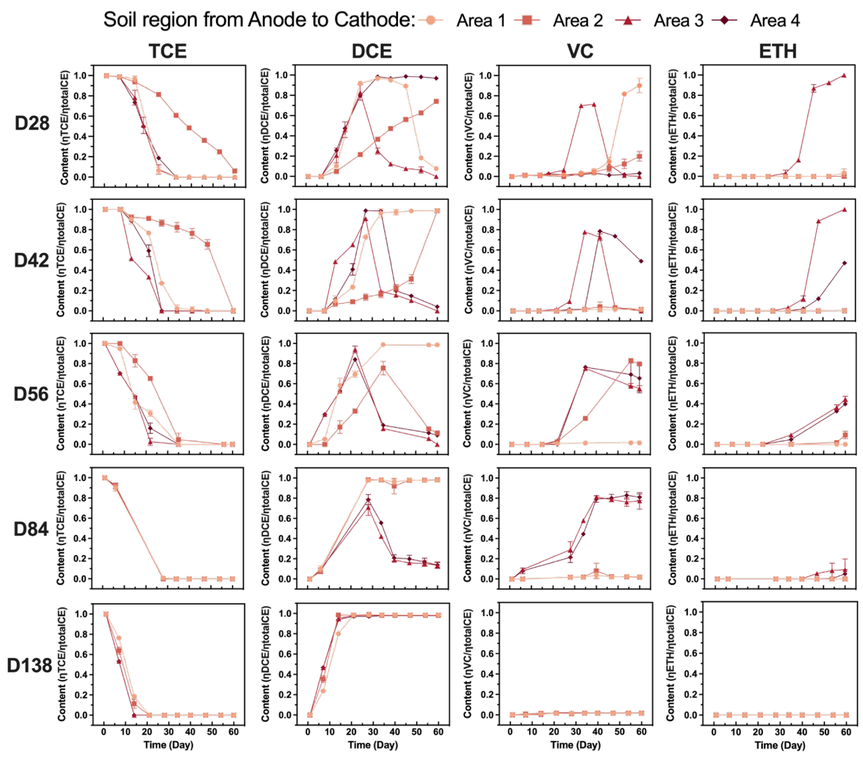
Figure 2



During the operation, a total of 9 rounds of 500 μM TCE was injected. Reductive degradation contributed to 46.52% of TCE removal. The dechlorination products consist of 30.6% ethelyn, 8.69% of VC, and 5.23% of DCE. The concentration of TCE in the pore water dropped from 500 μM to ~ 55.5 μM within 28 days and further reduced to 15.8 μM, resulting in over 95% TCE removal.

For the 1st step of dehalogenation (TCE–cDCE), the activity increased with the increased EK time and this step could be completed within 20 days after 138 days. In contrast, the dehalogenation activity of 2nd (cDCE–VC) and 3rd steps (VC–ETH) gradually diminished with continuous EK application, ultimately failing to achieve complete dechlorination to ETH.

Figure 3



For the biological analysis of the soil, *Dehalococcoides* was first enriched at Area 1 near the anode (3.12%), however, it did not become the dominant species, with a relative abundance of 0.023% to 7.6% among 138 days. After 138 days, the copies of *tceA* exhibited 3.7-fold higher than that of 28 days, illustrating the enhancement of 1st step reduction.

Figure 4

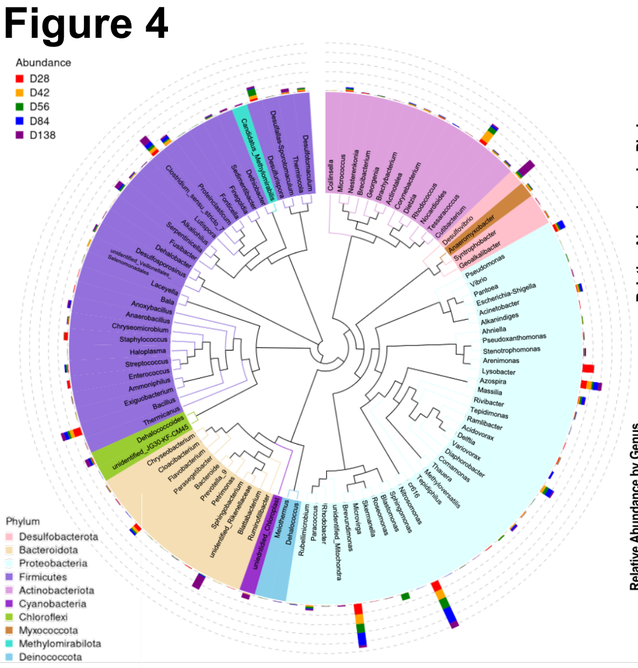
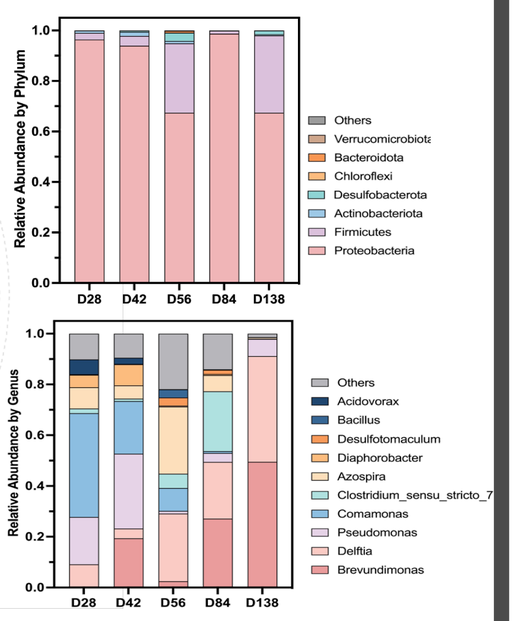


Figure 5



For the biological analysis of electrolytes, The presence of *Comamonas* (40.90%), *Pseudomonas* (18.63%) and *Diaphorobacter* (4.94%) at 28 days demonstrated that aerobic co-metabolism occurred in the electrode chambers. In the later stages, the replacement by *Brevundimonas* indicated that direct aerobic oxidation dominated in the later period.

Conclusion

- Re-inoculation of functional bacteria is required to sustain complete dechlorination from TCE to ethylene
- The aerobic respiration in electrolytes enriches the degradation pathways and compensates for the loss of 2nd and 3rd dehalogenation processes

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